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ABSTRACT

Collaborative projects are relatively complex and therefore are difficult to handle. Representing and analyzing social interactions among stakeholders in a systematic way are crucial to improving the collaboration productivity. This paper provides a generic modeling approach that explicitly represents the knowledge perspectives of stakeholders and their evolution traversing a collaborative process. This approach provides a mechanism to analytically identify the interdependencies among stakeholders and to detect conflicts and reveal their intricate causes and effects. Collaboration is thus improved through efficient conflict management. This paper also introduces a Web-based information system using the knowledge perspective model and the social network analysis methodology to support electronic collaboration.

Keywords

Social interactions, electronic collaboration, knowledge management, conflict management, information systems.

INTRODUCTION

To survive in today's increasingly competitive global economy, organizations have to face the question of how to effectively manage the distributed knowledge and processes to enhance the group productivity. Current developments of advanced Internet technologies and electronic business models have provided workable infrastructures for group communication and information processing. To effectively utilize these technologies to support teamwork, it is necessary to gain more fundamental understandings of the characteristics of the collaboration process. Published studies have shown that besides technologies, the social aspects are essential to the success of collaboration (Briggs, 2003; Erickson, 2000; Easley, 2003; Hardjono, 2001). One of the key social factors is the cognitive interaction process. As stakeholders' preferences, environments, and knowledge are dynamically changing during their interactions, collaborative activity over the Internet is more than an online data accessing and information sharing process. Accordingly, conflicts occur frequently and influence the project schedule and team performance. To improve the efficiency and effectiveness of collaboration, it is crucial to systematically model and analyze stakeholders' evolving understandings and systematically manage the conflicts. This paper presents a methodology for supporting conflict management within electronic collaboration by modeling and analyzing the stakeholders' social interactions. The methodologies to depict and control the evolution of distributed knowledge are introduced. This paper also describes a prototype collaboration support system developed for a US government research institute. It implements the methodology and uses the advanced network computing techniques to facilitate stakeholders' interaction within their work practice.

ISSUES OF SUPPORTING ELECTRONIC COLLABORATION

Electronic collaboration involves various stakeholders from different disciplines to work cooperatively over the distance and time boundaries. When many heterogeneous groups work together on large projects over a long period of time, their knowledge toward the system, the product, and other people will keep on evolving (Dym,1991; O'Leary,1998). The professional expertise in particular is framed by a person's conceptualization of multiple, ongoing activities, which are essentially identities, comprising intentions, norms, and choreographies (Carley, 1994; Erickson, 2000; Sowa, 1992).

Although the collaboration process might appear relatively technical, it is essentially a social construction process when different persons perform their tasks within various adaptive situations (Berger, 1966; Clancey, 1997; Clancey, 1993). The situations will eventually impact the changing of participants' roles and form a shared understanding (Arias, 2000). When stakeholders (i.e., all of the human participants and organizations who have influences on the collaboration process and the result) play their roles within a collaborative work, special education or experience enable a stakeholder to make particular decisions and make a contribution to the process. Traditional project management approaches usually define specific roles within which stakeholders use or apply their technical expertise. However, even within well-defined technical roles, every stakeholder makes the role "his own" by adapting or executing the role based on his conceptions and circumstances. It is the social interaction that determines the variation or adaptability of these roles in a particular application context. As the roles evolving, the ways stakeholders participate in the project and their learning customs will vary, which will directly or indirectly affect stakeholders' internal knowledge. Therefore, it is necessary to have well-developed methodologies for describing and analyzing the social interactions in collaborative contexts of the emerging practice.

During the collaboration the communication breakdowns and conflicts are often experienced because the stakeholders belong to different cultures that use different norms, symbols, and representations (Baron, 1984). Many methods and strategies have been developed to deal with different types of conflicts. Each of them is particularly useful in its special situation. Managing conflicts within collaboration is never a purely technical task. The same conflict can be resolved differently at different corporations due to their different cultures. The deficiency in the social interactions among the group is one of the major sources of conflict. Hence, to understand the social aspects of collaboration is indispensable for managing conflicts and improving the quality of tasks. Conflicts are not necessarily harmful since some of them can be used as means to expose problems and enhance group creativity. Understanding of engineering physics and corporate culture are both important to an efficient conflict management strategy. The question is how to capture those social aspects of the conflict management methods/strategies so that they can be used effectively in supporting collaboration. Another important issue is how to provide not only the strategies for people to resolve the conflict, but also the methods to explore new strategies by effective management approaches. To manage conflicts and facilitate their coordination, the information and knowledge models for each stakeholder must capture its domain expertise, as well as the particular viewpoints and perspectives toward the problems and the communities involved in the decision campaign. Coordination in collaboration has to be achieved through not only sharing of data and information, but also the realization of the decision contexts of each other (Kannapan, 1994). The decision context consists of at least two parts: the circumstances of the decision makers and the stages of the process. When people exchange information, they should understand under what circumstances this information is generated and in which situation it can be potentially used. Otherwise, it is difficult for them to interpret the purposes and implications of each other during the activity coordination. Therefore, to represent and organize the situated knowledge (i.e. the context) is essential to support the coordination among different groups. It is also of immense importance to understand how to design information systems so that they mesh with human behavior at the individual and collective levels. By allowing users to "see" one another, to make inferences about the activities of others, and to imitate one another, online collaboration platforms can become environments in which new social forms can be invented, adopted, adapted, and propagated—eventually supporting the same sort of social innovation and diversity that can be observed in physically based cultures (Erickson, 2000).

A FRAMEWORK TO SUPPORT ELECTRONIC COLLABORATION

To address these issues, our research is based upon a socio-technical framework to model the interactions within collaborations (Lu and Cai 2001). The framework addresses that one cannot utilize information to map from "what-to-do" to "how-to-do" in the collaboration process without knowing the perspective of the "who" that generates the information. Similarly, conflict resolution and control, both basic elements of decision-making in collaboration, require the explicit modeling of stakeholders' perspectives within their social interactions. A collaborative project is modeled as a co-construction process among a group of stakeholders. The key feature is to explicit model the "who" (i.e. the stakeholders' perspectives) within the process (i.e. the "what", "how", and "when"). The socio-technical framework focuses on representing and handling the interactions among the heterogeneous stakeholders and provides associations with other decision support models. It also defines methodologies for building and integrating various processes with the realization of sharing knowledge and managing conflict.

The socio-technical framework explicitly depicts the fundamental issues in supporting collaboration. It allows stakeholders to construct and manage collaborative activities by examining the characteristics of the three factors (i.e., process, stakeholders' perspective, and conflict management) (Figure 1). A systematic socio-technical analysis methodology is used to improve process and reconcile stakeholders' perspectives. In this methodology, conflict management strategies can be applied to construct and improve the collaboration processes through a feedback mechanism. It helps stakeholders generate specific strategies to monitor, refine, and control the collaboration by successfully managing conflict with different negotiation mediums.

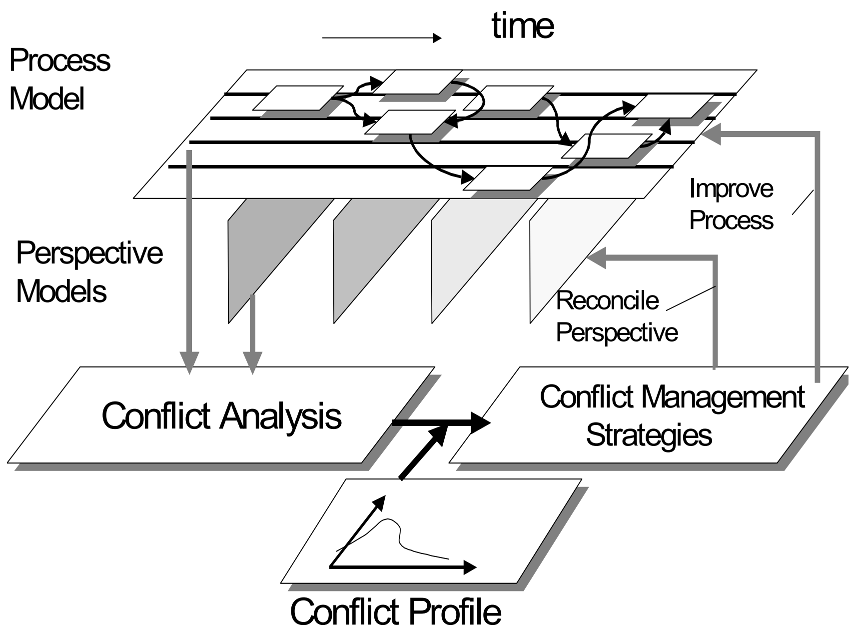

Figure 1. The Socio-technical Framework of Supporting Collaboration

SOCIAL INTERACTION MODELING AND CONFLICT MANAGEMENT

Methodology Overview

The central function of the research framework is the "socio-technical analysis" to model and analyze the social interactions within each step of the collaboration process. As shown in Figure2, the socio-technical analysis methodology takes three input parameters (i.e. the concept model, and the perspective model, the process model). The concept model is a structure which organizes the ontology models. It represents the shared or private notions of the stakeholders. The process model is a feasible computational model of a collaborative process to represent the interactions of individual tasks and to evaluate their affects to the enterprise goal and project objectives. It specifies the sequences and dependencies of decisions and actions to be jointly performed. The perspective model provides generic methods to formally capture, represent, and analyze stakeholders' knowledge perspectives and their interactions with each other. The concept model and perspective models represent the shared knowledge and social characteristics of various stakeholders during the collaboration process. They are derived from the surveys or knowledge base analysis conducted by collaboration information systems.

The dependencies among these models are represented as matrices for mathematical analysis. Conflict analysis applies systematic strategies to analyze inconsistencies by a thorough understanding of their various causes, effects, and processes. Various conflict management methods can be realized through controlling the interplay among these matrices. At a certain stage within the process, conflicts can be detected by tracking and comparing the "perspective states" of different stakeholders associated with a certain task. This analysis will derive three major outputs (i.e., process feasibility, conflict possibility, and perspective network). Then, based on these outputs, the systems can apply various control strategies so that the quality of the collaboration is enhanced. Control mechanisms adaptively handle the interplay among the three factors by systematically reconciling various perspectives, improving the processes, and controlling the product data and organizational structure.

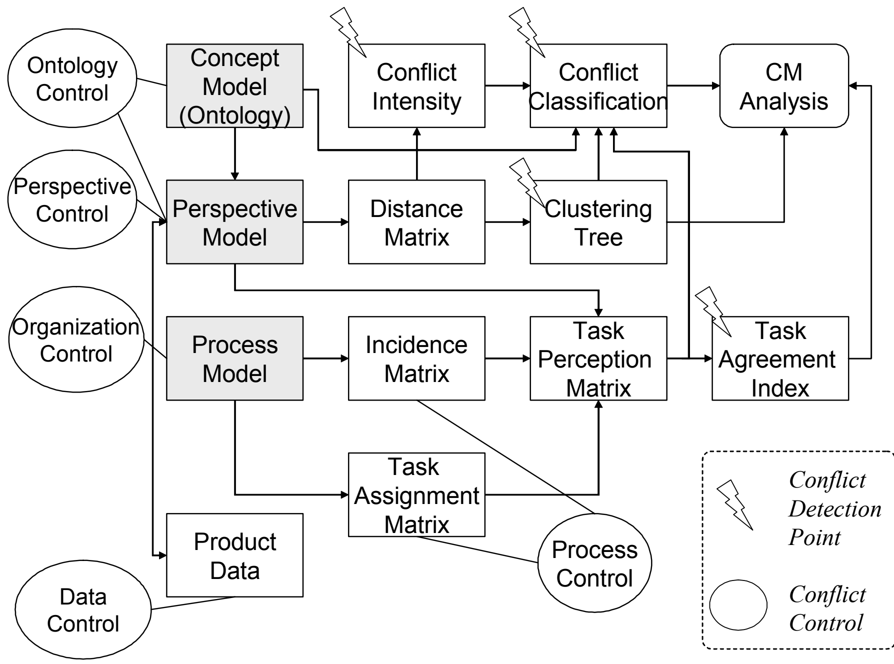

Figure 2. The Socio-technical Analysis Methodology

Social Interaction Modeling

The social interaction modeling mainly consists of building the concept model and the perspective model. While the process model depicts the tangible activities of the project, the concept model and perspective model track the knowledge evolution and social behavior changes along the collaboration progress.

Concept Structure Hierarchy

A concept model is a hierarchical structure that represents the organization of the ontology (Huhns, 1999) that stakeholders propose and use in their collaboration. Figure 3 shows a concept structure example of a product development team. Stakeholders may use both top-down and bottom-up construction methods (Vet, 1999) to build the concept structure. It is possible to apply some templates (e.g. "product function template", "organizational template", "conflict types template", etc.) to clarify the concepts. These templates act as the contend-based skeletons for organizing the external data that stakeholders may share with others. For more routine projects, stakeholders can extract many concept structures from previous decision models and work documentations.

When stakeholders propose new concepts, the concept structure is updated and is used to systematically organize these concepts and their relationships. When an individual proposes a new concept, he or she should first consider whether there are same or similar concepts in the structure. Thus, only the novel concepts can be specified and added. New concepts are often best generated by individuals, while the concept selection and enhancement are often best performed by the group. Therefore, we classify the concepts involved within the collaboration into two types. Shared concepts are those that have been well-defined from previous projects and have widely accepted meaning among the stakeholders (e.g., in the example shown in Figure 3, "Function Requirements", "Product", and "Organization" etc. are shared concepts). Private concepts are perceived only by some particular stakeholders. Their names or meanings are not expressed around the group. Whether a concept is shared or not is relative to the purpose of a certain group. If a group of people have a shared purpose toward a concept, it would be better to ask everyone to view it. Sometimes, a concept is not shared between two subgroups, but it might be shared within one subgroup. After the concepts are identified, the dependencies among these concepts can be further clarified by stakeholders. For instance, the concept "function requirements" in "technical decision" will influence the "function" of "product".

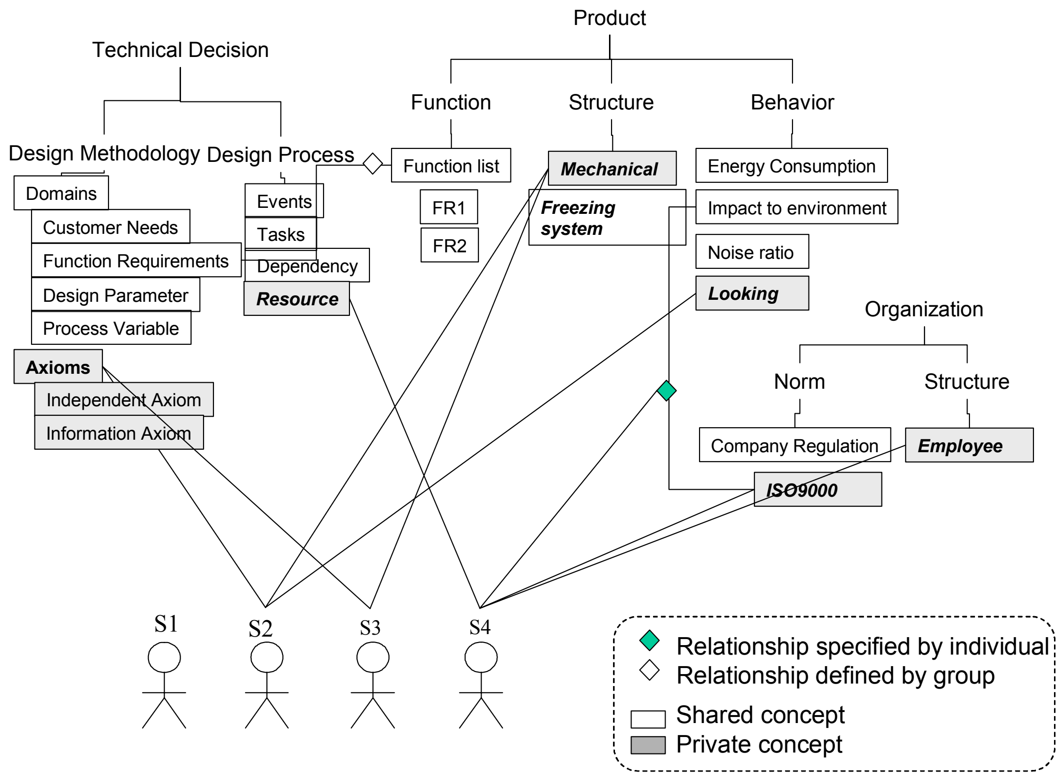

Figure 3. A Concept Structure Built by Stakeholders in a Collaborative Design Project

Perspective Model

A perspective model is the special information to represent the status of a stakeholder's perspective at a certain time. Our understanding of knowledge perspectives is based on the following acknowledgements. First, each individual builds over her lifetime an evolving base of information that is "internal" to her. Second, each individual has a perspective that evolves over time and acts like a "lens" through which she understands and collects data external to her. Third, the data that each individual produces, or exchanges through any medium (e.g., computers, speech, and writing), is the external manifestation of her internal information, appropriately filtered through her "perspective lens".

A perspective model consists of the purpose (i.e. the intention to conduct certain actions), context (i.e. the circumstances in which one's action occurs), and content (i.e. what one knows and understands) that the stakeholder uses to access the external knowledge and to expose the internal knowledge. In information systems, perspective model can be depicted as a data format with dependencies to other information entities. Our research develops a format of representing perspectives and a procedure to capture, generate and analyze perspective models.

Given the well-organized structure of concepts, it is feasible to ask the stakeholders to build the perspective model state diagrams (PMSD) at a certain time. A stakeholder's PMSD attempts to depict the explicit relationships among his/her concepts (include the shared concepts and private concepts) and his/her purpose, content, and context information. The concepts listed in the PMSD are categories of perspective contents relating to stakeholders. Using the concept structure to generate the PMSD provides a structured way for us to systematically compare and examine the perspective differences among stakeholders.

Each concept of the concept model can be associated with a stakeholder by a set of purposes, contexts, and contents. The operation is to ask the stakeholders to:

- First, relate this concept to their purposes. A stakeholder is able to specify his/her intentions within the project for a given concept. There might be more than one purpose relating to one concept. For an abstract concept, the purpose could be more general. For a specific concept, the purpose is more detail.

- Second, specify the relationships of this concept to other concepts based on his/her context. If there are a new concept generated, add it to the PMSD architecture and set it as a private concept.
- For each concept, declare or relate his/her own knowledge, document, and data about that concept and put them as the parts of the content associated with that concept.

Therefore, a PMSD is the picture that depicts a snapshot of a stakeholder's perception of concepts. It embodies his/her related purposes, context, and content. In a collaboration support system, a PMSD is represented as XML formats to facilitate analysis.

Social Interaction Analysis

By comparing and analyzing stakeholders' perspective models it is possible to determine the degree of agreement among their opinions during their interaction. As shown in Figure 4, given the PMSDs for certain stakeholders, we can ask them to review the perspective models of each other. The review information is used to compare the perspective models and determine the similarity of two stakeholders' perspectives toward a shared concept. We can also aggregate multiple stakeholders' perspective models and compare their general attitudes at different levels of abstraction. Furthermore, we can track the evolution of the perspective model based on the clustering analysis results. The procedure is called a social interaction analysis (Figure 4).

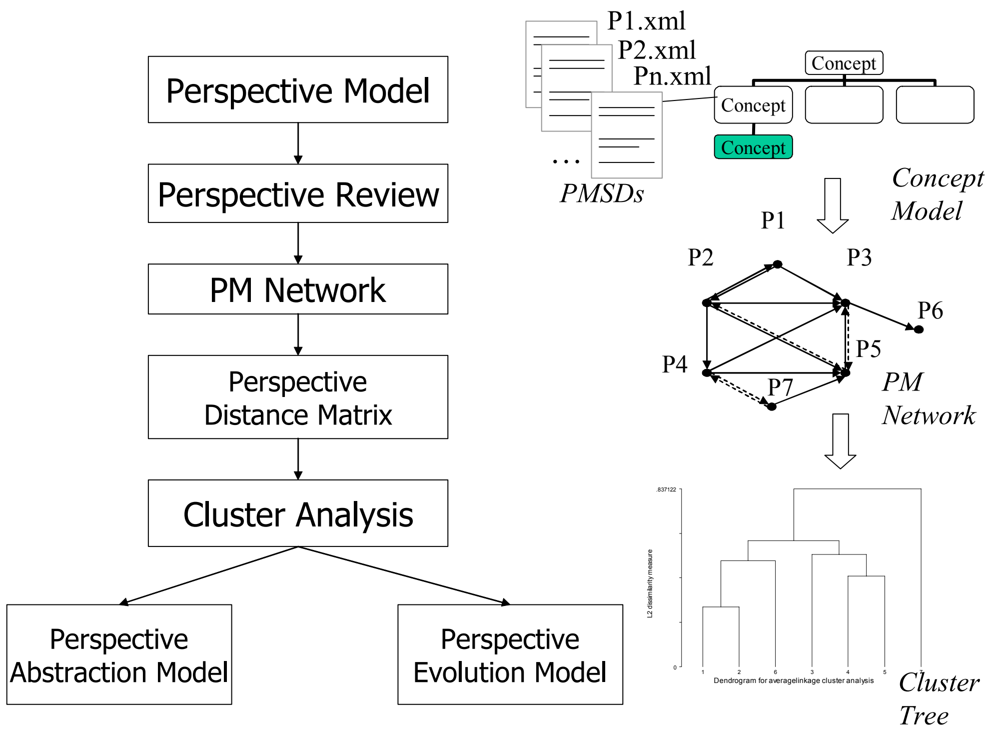

Figure 4. The Social Interaction Analysis Procedure

The first step is to determine the inconsistency (i.e. the "distance") among a group of perspective models. There are two approaches: the intuitive approach and the analytical approach. The intuitive approach relies on the insights of the stakeholders. The analytical approach uses mathematical algorithms to derive distance through "positional analysis", which is based on a formal method used in social network analysis (Wasserman, 1994). This approach views the perspective models of a group of stakeholders toward a single concept as a network of opinions associated with each other. In this network, a stakeholder, who possesses a perspective model, has relationships with others' perspective models. We define these relationships as their perceptional attitudes toward each other. A group of perspective models towards a given concept are placed as a graph (i.e., a PM network). The means that we use to compare the perspective models is based on analysis of the structure of the PM network. Two perspective models are compatible (or similar) if they are in the same "position" in the network. In the social network analysis, "position" refers to a collection of individuals who are similarly embedded in networks of relations. If two perspective models are structurally equivalent (i.e., their relationships with other perspective models are the same), we assume that they are purely compatible and there are no detectable differences. That implies that they have the same perception towards others and others have same perception towards them (i.e. zero distance).

A distance matrix is derived for each PM network. It represents the situation of perspective compatibility among a group of stakeholders for a given concept. We can also compare stakeholders' perspective models for multiple concepts by measuring the structural equivalence across the collection of perspective model networks (i.e., a PM network set). Perspective distance matrices serve as the basis for cluster analysis. Hierarchical clustering is a data analysis technique that is suited for partitioning the perspective models into sub-classes. It groups entities into subsets so that entities within a subset are relatively similar to each other. We apply hierarchical clustering to the distance matrix to generate a tree structure (or a dendrogram), which shows the grouping of the perspective models. These analysis results illustrate that the perspective models are grouped together at different levels of the cluster tree (Figure 4).

The cluster tree exposes interesting characteristics of the social interactions. Within a collaborative project, the participants of the organization cooperate and build the shared reality (i.e. the common understanding of the stakeholders towards certain concepts) in the social interaction process (Berger, 1966). Understanding the process of building shared realities is the key to managing social interactions. The shared reality can be represented by the abstraction of close perspective models among a group of stakeholders. As a matter of fact, the cluster tree depicts the structures of the shared reality, since a branch of the clustering tree at certain level implies an abstract perspective model with certain granularity. The height of the branch indicates the compatibility of the leaf perspective models. A cluster tree with simple structure and fewer levels implies that all of the perspective models have similar attitudes (or positions) toward others.

While the perspective models are changing, the clustering analysis can be used as a systematic way to depict the transform of the perspective models. The change of the cluster trees at different stages of collaboration reveals the characteristics of perspective evolution. We can investigate the changes of the topological patterns of the clustering trees within the collaboration process to derive ways to interfere in the perspective evolutions.

Conflict Management

Given the condition that the social interactions are analytically measured, control mechanisms can be derived to manage the evolutions of the perspective models and therefore to support collaboration. They can be classified into the following strategies.

Process Control

The perspective analysis can be performed to all of the stakeholders who might act or influence a task. By evaluating the perspective compatibility and the execution feasibility of future tasks, which are in the plan but have not be conducted yet, we can prevent some conflicts by noticing their potential existence earlier. By providing certain information to stakeholders, it is possible to change the perception matrix and therefore to increase the perspective consistency of a task. It is possible to directly adjust the sequences and dependencies among the tasks to maintain the integrity of the opinions of stakeholders.

Perspective Control and Ontology Control

First, it is possible to directly influence stakeholders' perspectives (their content, purpose, and context) to maintain the integrity and compatibility of the opinions toward a certain concept or task. Analyzing social interactions will identify the perspective models with low similarities and reveal the conflicts clearly. Thus, we can focus on the stakeholders who have singular perspectives and understand their rationale. Second, communication channels can be built to increase the interaction opportunities among stakeholders with different perspective models. The group can manipulate the concept structure through clarifying the meanings and definitions of critical concepts so that people have shared understanding. It is also feasible to serve stakeholders with different concepts to isolate their perspectives. An opposite way is to use conflicting perspectives as means to enhancing brainstorming and innovation. Third, strategies can be derived to manage the conflicts through influencing stakeholders' information access and comprehension during the collaboration. Possible solutions include providing suitable trainings based on their perspectives and the job requirements, assisting the critical stakeholder to review the relevant information during certain conflicting tasks, and recording the discussions about the shared concept for future reuse.

Organization Control

The clustering tree shows the grouping features of stakeholders' perspectives. Using different organizational structures will change the communication channels and the perception distances. If two stakeholders are separated into different groups, the possibility of interaction will decrease. We can change the task assignment or modify stakeholder' roles to affect their contexts. It is even possible to add or remove stakeholders associated with a certain task to avoid the conflicting situation or to move the stakeholders with similar perspectives together.

Data Control

This control mechanism is to affect the conflicts through appropriately providing and handling external data, which will be viewed and consumed by the stakeholders. Examples are to use consistent checking and version control mechanisms to maintain the product data integrity, to track the changes of shared data by referencing to the perspective changing, and to map the shared data to perspective models so that the system realizes the specific impact of the conflicts towards working results.

BUILDING ELECTRONIC COLLABORATION SUPPORT SYSTEMS

The social interaction modeling and conflict management methodology can provide a theoretical basis for building new electronic collaboration systems. The STARS system is a prototype system to support collaboration over the Internet. It is also developed as an experimental apparatus for testing the research methods. The system implements the process modeling, perspective modeling, and socio-technical analysis methodologies. On the other hand, it collects process and perspective data once stakeholders use it as a collaboration tool. By investigating the collected experimental data, we can determine the effectiveness of the approach and therefore improve it.

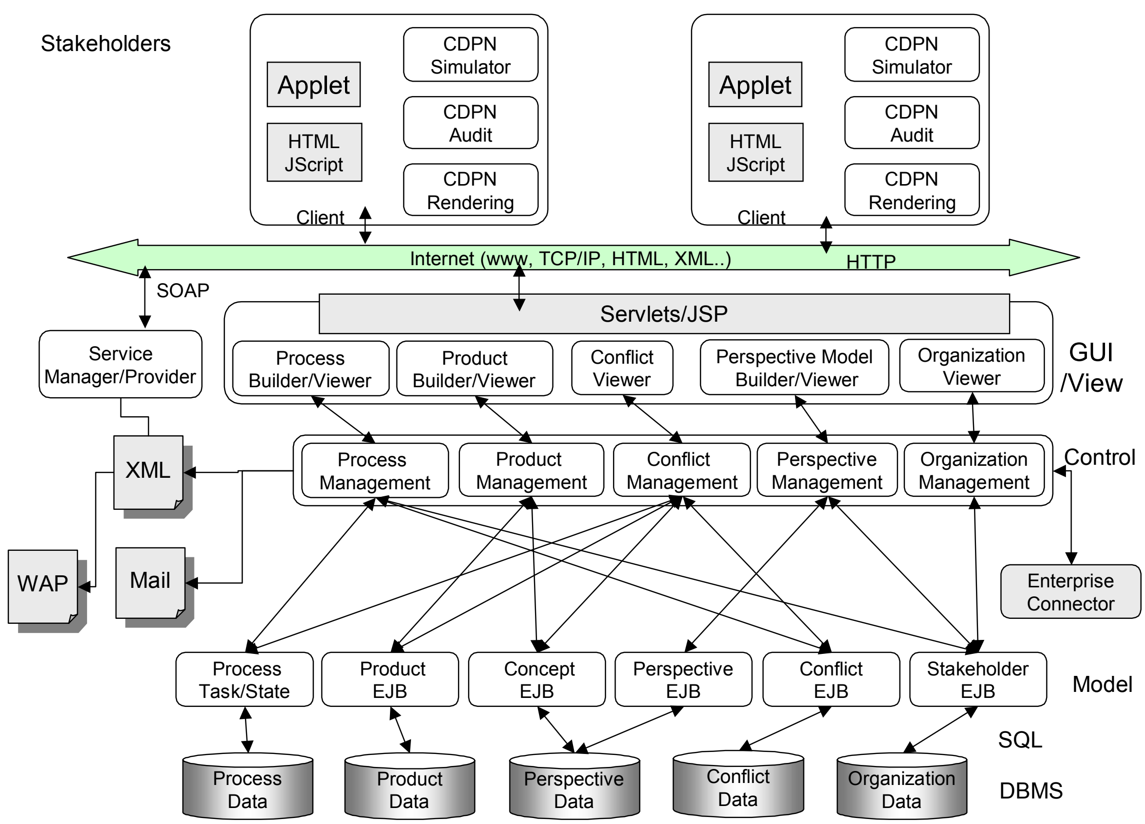

Figure 5. STARS System Architecture

STARS system provides a web-based environment that supports the collaboration process representation, conflict management, and knowledge integration within a project team. Stakeholders' perspectives are modeled and analyzed in the system and their roles in the collaboration tasks are depicted. Advanced communication tools with networking and remote database accessing functions support the stakeholders to declare, share, and modify their perspective models using browsers. The system implements the functional modules (e.g. perspective management, process management, conflict management, etc.) by using J2EE1.4 and Web Services technologies (Figure 5). The system provides methods to detect, analyze, and track the conflicts during collaboration. It also supports the business-to-business process communications. Figure 6 shows the knowledge perspective management module that allows stakeholders to declare and review their perspective information according to a concept structure tree. The system can analyze the perspective models, detect and predict conflicts, and suggest possible control strategies.

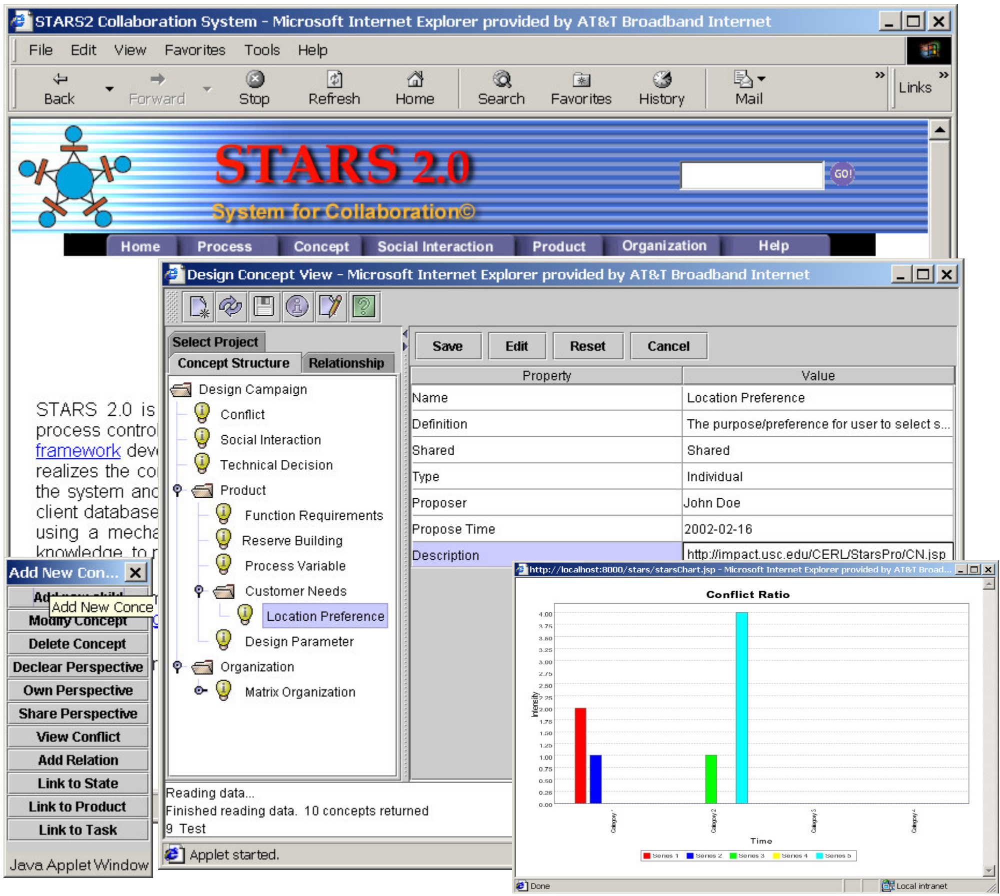

Figure 6. The Perspective Management and Conflict Management Modules of STARS

Groups of designers, business analysts, and consultants working in a U.S. national construction research institute have been using STARS in their small projects. Feasibility and computability of the analysis algorithms were proved. The results of using the system were investigated and compared with results obtained in their absence. The stakeholders who participated in the experiment considered that using the social interaction modeling methodologies could accelerate their learning process and detect conflicts earlier in their collaborative projects. The causes of breakdowns of collaboration are more comprehensible when applying the analysis methodologies.

CONCLUSION

This paper presents a systematic approach to supporting online collaboration by modeling and analyzing stakeholders' social interactions. To address the issues of electronic collaboration, this research develops a computational social interaction modeling and analysis methodology based on the social construction theory. This approach provides methods for capturing perspectives and understanding their relationships to facilitate the control of the evolution of the shared insights. It avails conflict management by systematically facilitating the manipulation of the process, the perspectives, the organizational structure, and the shard data. The STARS system was built to improve the coordination among stakeholders. Its social interaction modeling function provides an efficient way for stakeholders to understand the meanings and improve coordination during their collaboration over the Internet.

This research has some limitations. First, the closed-loop perspective management methodology requires stakeholders to be actively involved in the building and updating of perspective models. This might be overkill when the group is already very efficient and stable. Second, using the perspective analysis requires the computing tool and introduces a higher level of complexity. The system users have to be able to honestly and clearly specify their understandings toward the concepts and others' perspectives. In the future, the social interaction analysis model can be improved by applying advanced statistics and econometrics techniques. It is also important to generate dynamic modeling methods to define the relationships between the evolution of perspective model and the quality of online collaboration.

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